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(54) Subcutaneous defibrillation electrodes

Subkutane Elektroden zur Entflimmerung

Electrodes de défibrillation sous-cutanées

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Description

BACKGROUND OF THE INVENTION

The present invention relates to field of electrical defibrillation, including cardioversion, and more particularly to the structure for an electrode used in implantable defibrillation systems. The term "defibrillation", as used herein, includes cardioversion which is another technique involving relatively high energy delivery, as compared to pacing, as well as other aspects of defibrillation therapy such as the monitoring of cardiac electrical activity (sensing) when not delivering high energy impulses.

Defibrillation is a technique employed to counter arrhythmic heart conditions including some tachycardias, flutter and fibrillation in the atria and/or ventricles. Typically, electrodes are employed to stimulate the heart with electrical impulses or shocks, of a magnitude substantially greater than pulses used in cardiac pacing. One defibrillation approach involves placing electrically conductive paddle electrodes against the chest of the patient. During cardiac surgery, such paddles can be placed directly against the heart to apply the necessary electrical energy.

More recent defibrillation systems include body implantable electrodes. Such electrodes can be in the form of patches applied directly to epicardial tissue, or at the distal end regions of intravascular catheters, inserted into a selected cardiac chamber. U.S. Patent No. 4,603,705 (Speicher et al), for example, discloses an intravascular catheter with multiple electrodes, employed either alone or in combination with an epicardial patch electrode. Compliant epicardial defibrillator electrodes are disclosed in U.S. Patent No. 4,567,900 (Moore).

Epicardial electrodes are considered the most efficient, in the sense that less energy is required for defibrillation as compared to either chest contact paddles or intravascular catheter electrodes. However epicardial electrode implantation is highly invasive, major surgery, since it is necessary to enter the chest cavity, which typically involves spreading of adjacent ribs or splitting of the sternum. This procedure presents a risk of infection. Further, implantation and attachment place physical constraints upon the nature of electrode. These electrodes must be either quite small, or extremely compliant and resistant to fatigue, as they maintain conformal fit to the contracting heart.

Generally, larger defibrillation electrodes are considered more desirable, since they reduce the impedance at or near the electrode. Sensing artifacts also are reduced for larger electrodes. However, larger electrodes are difficult to attach to the epicardium, as they must conform to the heart during the contractions associated with normal cardiac activity. Subcutaneous electrodes are more easily implanted, at less risk to the patient. In a defibrillation electrode or any other implanted device, however, increasing the size generally increases discomfort and surgical risk to the patient.

Increasing the size of a defibrillation electrode affects its electrical performance. Conventional electrodes are subject to "edge effects" arising from the non-uniform distribution of electrical energy when the electrode receives the pulse. In particular, current densities are greater at the edges of the electrode than at interior regions of the electrode. An attempt to counter the edge effect is disclosed in U.S. Patent No. 4,291,707 (Heilman et al). A series of circular openings, through an insulative layer framing a conductive screen, are said to substantially eliminate the edge effect by the additional exposure of the screen. Another problem encountered in larger electrodes is the resistance across the length (largest linear dimension) of the electrode, leading to unwanted voltage gradients across the electrode which can degrade electrode performance.

Therefore, it is an object of the present invention to provide an implantable defibrillation electrode with a large effective surface area to lower the impedance at or near the electrode, without causing undue patient discomfort.

Another object is to provide a defibrillation electrode that has a large effective area, yet is easier to implant and readily conforms to the contours of its implant location.

A further object is to provide a defibrillation electrode structure enabling a relatively large size while reducing the non-uniform field distribution associated with conventional electrodes.

Yet another object is to provide defibrillation electrodes of sufficient size and effectiveness to enable transthoracic delivery of defibrillation pulses, with an implanted systems.

EP-0 317 490 discloses a method and apparatus for implanting an automatic implantable defibrillator in which an electrode, which is preconfigured as, for example, a spiral, is straightened during insertion through a catheter and reforms upon emergence from the catheter to approximate the function of a paddle-type electrode.

US-3,333,045 discloses a body implantable electrical conductor lead assembly in the form of a helical cable of silver coated stainless steel wires loosely fitted into a silicone rubber tube to provide enhanced flexibility and low resistance. The cable comprises a plurality of drawn, brazed stranded wires.

WO 89/06148 discloses an intravascular electrode lead arrangement comprising a number of elongate flexible electrodes which are laterally retracted to positions adjacent and parallel to one another for insertion into an atrial or ventricular room. Upon insertion, the flexible electrodes are laterally expanded, or splayed, in order to bear resiliently against the surrounding walls of the room.

EP-0 428 279, which is prior art only by virtue of Article 54(3), discloses an electrode lead for implantation comprising a trifurcation of electrically conductive wire braids, the braids being substantially parallel and laterally spaced sufficiently that they may be fitted into adjacent intercostal spaces.

SUMMARY OF THE INVENTION

To achieve these and other objects, there is provided a body implantable tissue stimulating electrode as recited in Claim 1. The electrode includes a plurality of flexible, electrically conductive electrode segments preferably having a nominal width and a length at least five times the nominal width. A means may be provided for mechanically coupling the electrode segments with respect to one another whereby each of the segments, over the majority of its length, is spaced apart from each one of the other segments by a distance of at least 1.5 cm. A means is provided for electrically coupling the electrode segments for substantially simultaneous reception of the tissue stimulating electrical pulses from a pulse generating means. Consequently the electrode segments, when receiving the tissue stimulating pulses, cooperate to define an effective electrode area incorporating the electrode segments and having a width of at least 1.5 cm.

In one preferred configuration, the electrode segments are linear and in parallel spaced apart relation, all extending in a longitudinal direction. The mechanical and electrical coupling means can be a transversely extended distal portion of an elongate, electrically conductive lead. The lead is connected to each of the respective first end portions of the electrode segments along its distal region, and connected at its proximal end to a pulse generating means. Preferably an electrically insulative layer covers the lead, leaving the electrode segments exposed, to define a substantially rectangular "phantom" area or effective electrode area.

Alternatively, the electrode segments can radiate outwardly from a common junction, typically at the distal end of the lead or conductive coupling wire from the pulse generating means. While the coupling wire is covered with an insulative material over the majority of its length, a distal end portion of the coupling wire can be left exposed, to provide one of the electrode segments.

Yet another approach involves a single electrically conductive wire or path, with portions of the path providing the spaced apart segments. As an example, the path can be arranged in a serpentine configuration in which segments are parallel to and aligned with one another, side by side. Alternatively, the conductive path is formed as a spiral. In either event, adjacent segments are spaced apart from one another a distance substantially greater than their width, preferably by an order of magnitude or more.

In a preferred example, elongate electrode segments about 30 cm long and with a nominal width of 0.5 mm extend longitudinally, aligned with one another and spaced apart from one another by about 3 cm. One end of each electrode segment is mounted to the distal end portion of a conductive lead to a pulse generator. At the opposite, free end of each segment is an enlargement such as a loop or flared end, formed to minimize local high current densities due to the previously described edge effects. The combination of a large phantom area with multiple conductive segments reduces non-uniform current distributions.

The best results are achieved with highly conductive electrode segments. Accordingly, the segments are preferably formed of low resistance composite conductors including drawn braised strands (DBS), drawn filled tubes (DFT) and the like, coated with platinum or another metal from the platinum group, e.g. iridium, ruthenium or palladium, or alternatively with an alloy of one of these metals. The strands can be formed of titanium or platinum. A suitable filled tubular conductor is composed of a silver core within a stainless steel tube.

It has been found that highly conductive electrode segments reduce any voltage gradient across the electrode, with the separate segments simultaneously receiving a defibrillation or other stimulation pulse. The separate segments thus cooperate to act as a single "patch" electrode, having an effective surface area equal to that of a rectangle or other polygon containing all of the segments. As an example, an electrode formed as a row of five parallel electrode segments spaced apart from one another by 3 cm, each segment being 10 cm long, would have a rectangular phantom or effective area slightly larger than 120 (twelve times ten) square cm. Yet, as compared to a continuous rectangular patch electrode measuring ten by twelve cm, the branched segment electrode in accordance with the present invention is easier to implant, reduces the high current density regions, and more easily conforms to the thorax or other surface to which it is attached. In fact, branched arrangements of segments can provide effective defibrillation electrode areas in the range of from 100 to 200 square cm, while enabling easy implantation.

If desired, one or more electrodes implanted proximate the pleural cavity and rib cage can be used in combination with one or more coil electrodes mounted on an intravascular catheter, preferably positioned in the right atrium and the right ventricle of the heart, with the distal end of the catheter near the apex of the right ventricle.

As compared to the entry into the chest cavity normally associated with implanting epicardial electrodes, transthoracic placement of subcutaneous electrodes as outlined above is substantially less invasive, preserves the integrity of the rib cage and the pleural cavity, and reduces risk of infection.

Nonetheless, other implant locations, including direct attachment to epicardial tissue, can be employed to achieve relatively large effective electrode areas while maintaining patient comfort with substantially more uniform distribution current density.

IN THE DRAWINGS

For a further understanding of the above and other features and advantages, reference is made to the detailed description and to the drawings, in which:

Figure 1 is a top plan view of a defibrillation electrode constructed in accordance with the present invention;

Figure 2 is a sectional view taken along the line 2-2 in Figure 1;

Figure 3 is a sectional view taken along the line 3-3 in Figure 1;

Figure 4 is a top plan view of an alternative electrode;

Figures 5-9 illustrate alternative constructions for electrode segments of the electrodes;

Figure 10 is plan view of another alternative embodiment electrode constructed in accordance with the present invention;

Figures 11-13 illustrate further alternative configurations of the electrode of Figure 9;

Figure 14 is a top plan view of another alternative embodiment electrode;

Figures 15, 16 and 17 illustrate a further electrode;

Figure 18 is a top plan view of yet another embodiment electrode;

Figure 19 is a schematic representation of the electrical field between a continuous patch electrode and an electrode having segments, but in which the segments are too close to one another;

Figure 20 is a schematic representation of the electrical field between two electrodes constructed according to the present invention;

Figure 21 is a plot of intraelectrode impedance as a function of the spacing between adjacent segments of each of the electrodes, for electrodes with from two to four segments; and

Figures 22, 23 and 24 diagrammatically illustrate alternative implantation approaches for defibrillation systems incorporating electrodes embodying the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning now to the drawings, there is shown in Figure 1 a defibrillation electrode 16 including three parallel and spaced apart electrode segments 18, 20 and 22. Each of the segments has a length (L in the figure) substantially longer than its width (W), e.g. 30 cm long with a nominal width preferably about 0.5 mm. Generally, the width should be within the range of from 0.25-5 mm. Adjacent segments are spaced apart a distance (D) substantially greater than the nominal width, e.g. 3 cm. This center-to-center spacing should be at least 1.5 cm, and preferably does not exceed 30 cm.

Electrode segments 18, 20 and 22 are fixed at respective first ends to a distal end portion 24 of an electrically conductive lead 26. The lead conducts electrical pulses to the electrode segments from a pulse generator (not shown) coupled to the proximal end of the lead. Lead 26 at the distal end structurally supports the longitudinally extended electrode segments in the transversely spaced apart configuration shown.

The electrically conductive portion of lead 26 is surrounded by an electrically insulative cover or sheath 28, preferably constructed of a body compatible polymer, e.g. a medical grade silicone rubber or polyurethane. As seen in Figure 2, the lead includes a composite conductor formed of a core 30 of silver surrounded by a tube 32 of stainless steel. This type of composite conductor is known as drawn filled tube (DFT) of MP35N (brandname) alloy available from FWM Research Products of Fort Wayne, Indiana. Further, a coating 34 of platinum is applied over the stainless steel, preferably by sputtering or other deposition process. While preferably platinum, coating 34 also can consist of another metal from the platinum group (e.g. iridium, ruthenium and palladium) or an alloy of these metals. Insulative sheath 28 is contiguous with and surrounds the platinum layer.

As seen in Figure 3, the construction of electrode segment 22 (and likewise segments 18 and 20) over substantially all of its length is substantially similar to the construction of the conductive portion of lead 26. Thus the segments also are highly electrically conductive. Platinum coating 34 provides a further advantage for the segments, which are not covered by the insulative sheath. In particular, the platinum coating when applied by vapor deposition provides a microtexture which substantially increases the reactive surface area of the electrode segments, to reduce near field impedance of the electrode (the term "near field" impedance refers to the voltage losses associated with the electrode due to chemical and field effects). For a further discussion of this feature, reference is made to U.S. Patent 5,074,313 assigned to the assignee of the present application. The reduced interface impedance increases the ratio of bulk impedance to the total system impedance as measured between the stimulating electrode and the indifferent or signal return electrode. Thus, more of the voltage drop occurs across tissue, where it is useful for causing the desired stimulation, with proportionately less of the voltage drop occurring at the electrodes where it is non-productive. This enables a reduction in overall potential or pulse duration, in either event reducing the required energy for defibrillation.

Given adequate separation between segments 18, 20 and 22, the current distribution is made more uniform. To further counter any current density differentials due to edge effects at the ends of segments 18, 20 and 22, loops 36, 38 and 40 are formed at these ends, respectively. Alternatively, the ends can be flared or otherwise enlarged, and remain substantially free of undesirable concentrations of high current. Such enlargements also facilitate implant, as they tend to positionally fix the electrode segments.

Because the electrode segments are electrically common, the electrodes receive and transmit defibrillation pulses simultaneously. The electrode segments are sufficiently near one another to function in concert, providing an effective area or phantom area incorporating the segments, as indicated in broken lines at 42. In other words, electrode segments 18, 20 and 22 define a gen-

erally rectangular effective area, with substantially greater compliance to contours and movements of body tissue, as compared to a continuous patch electrode. In addition, the spacing between electrodes performs an important electrical function by producing a substantially more uniform current distribution than that of a continuous patch electrode. Patch electrodes are known to have regions of very high current density around their outside edges, and regions of low current density at their centers. By using a segmented electrode, with segments properly spaced apart from one another, much higher currents can be delivered to the central region of the effective or phantom area because current is able to flow between adjacent segments. This results in a more uniform electrical field across the heart.

Figure 4 illustrates an defibrillation electrode 44 including five elongate electrode segments 46, 48, 50, 52 and 54, each with a preferred width and substantially greater preferred length as described in connection with electrode 16. Each of electrode segments 46-54 is part of a wire mesh pattern 55 and extends longitudinally. Transversely extended end portions 56 and 57 of the pattern couple the segments to a lead 58. An insulative sheath 62 surrounds lead 58 from electrode 44 to the proximal end of the lead. An electrically insulative backing 64 supports mesh pattern 55. The mesh pattern is covered by an insulative layer 66. Slots 68, 70, 72 and 74 are formed in backing 64 and layer 66 between adjacent electrode segments.

Figure 5 illustrates an alternative form of composite conductor known as DBS (drawn braised strands), available from FWN Research Products, Fort Wayne, Indiana. As shown, a silver core 73 is surrounded by six stainless steel wires 75. The structure is heated and drawn to braise all wires together. The results is a solid, continuous composite conductor composed of a silver core and a stainless steel outer shell or tube.

Figure 6 illustrates an alternative construction for the electrode segments of either electrode 16 or electrode 44, involving a plurality of composite conductors 76 in a twisted configuration. Each of the conductors can include a silver core within a stainless steel tube coated with platinum as previously described. Alternative composite conductors for single and multiple wire arrangements include platinum or titanium ribbon or wire, clad with platinum. The twisted construction enhances flexibility and resistance to fatigue in the electrode segments. Other alternatives include braided or knitted wires.

Figure 7 shows another construction for the electrode segments, in the form of a woven mesh or screen 78 on an electrically insulative backing 80. This type of electrode segment construction is particularly well suited for epicardial positioning, e.g. with electrode 44 in Figure 4.

Another alternative segment construction, shown in Figures 8 and 9, involves a flexible, electrically insulative cylindrical core 82 of polyurethane, medical grade silicone rubber, or other suitable body compatible material. Core 82 is surrounded by an electrically conductive coil winding 84, preferably a wire or composite cable such as illustrated in Figure 2. The helically wound coil conductor provides the greatest flexibility and fatigue resistance of any of the arrangements discussed, and for this reason is preferred in the case of direct epicardial attachment, or any other implant location in which the lead segments are subject to continued or repeated muscular contraction or other abrupt tissue movements. A disadvantage, relative to other embodiments, is that a helical coil electrode segment, as compared to other segments of equal length, involves a substantially longer conductive path with less tensile strength.

All of the alternative constructions provide electrode segments which are highly compliant, first in the sense that they readily adjust to the contours of body tissue at the implant site when they are implanted, and secondly over the long term, in continually conforming to the tissue during muscular contractions and other tissue movement.

Figure 10 illustrates a further embodiment defibrillation electrode 86 including electrode segments 88, 90 and 92 formed as branches, radiating or extended outwardly from a common junction and stress relief area 94. Junction 94 is positioned at the distal tip region of a lead 96 to a pulse generator (not shown), and includes a conductive portion surrounded by an insulative sheath 98. The conductive region of the lead and the electrode segments can be constructed as previously described.

The stress relief portion of the electrode is electrically insulative and covers portions of the segments, leaving exposed portions of the segments spaced apart from one another and defining an effective or phantom area 100 shown by the broken line. As before, segments 88-92 have a nominal width preferably about 0.5 mm, and are longer than they are wide, for example by at least a factor of five. At the free ends of the segments are respective masses or bodies 102, 104 and 106. The bodies are constructed of an electrically conductive, plastically deformable material such as platinum or gold and, as seen in Figure 10, include slots 108 slightly wider than the thickness of segments 88-92. Each body is applied to the free end of its respective electrode segment by inserting the free end within the respective slot and pinching the body to frictionally secure the body to the electrode segment. Bodies 102-106 thus provide enlargements at the free ends of the segments to reduce the chance for high current densities at the free ends, and provide a means of fixation of the free ends.

Figures 11-13 schematically illustrate alternative configurations for electrode 86. More particularly, Figure 11 illustrates a clamp 110 for electrically and mechanically coupling two intersecting cables 112 and 114. Cable 112 is part of lead 96, with a distal portion of the lead providing center segment 90. Electrode segments 88 and 92 are opposite portions of cable 114. An extension 116 of electrically insulative sheath 98 covers clamp 110 and portions of cables 112 and 114, leaving the segments exposed.

In Figure 12, segments 88, 90 and 92 extend radially from a crimping member 118 at the distal end of lead 96. Alternatively, segment 90 is the distal end of the lead, in which case the remainder of the lead, crimping member 118 and portions of the electrode segments are provided with an insulative covering 119.

In Figure 13, crimping member 118 secures electrode segments 88, 90 and 92 to the distal section 120 of lead 96. Insulative sheath 98 leaves distal section 120 exposed, so that it functions as a fourth electrode segment.

Figure 14 shows a further embodiment defibrillation electrode 122 including a lead 124 having a distal end 126 formed in a curved, serpentine configuration. An insulative sheath 128 covers the lead and leaves the distal region exposed. Further insulation covers curved portions of the electrode at 130, 132 and 134, thus to define four parallel segments or length-portions 136, 138, 140 and 142 aligned with one another and side by side.

Figures 15, 16 and 17 disclose alternative serpentine electrode configurations including an electrode 144 with a wire mesh or screen 146 on an electrically insulative backing 148. Figures 15 and 16 illustrate a conductive path 150 including parallel electrode segments 152, 154, 156 and 158. The distal end of segment 158 is enlarged at 160 to counteract edge effect current densities.

In Figure 17, an electrode 162 includes a serpentine conductive path 164 formed between a pair of generally rectangular electrically insulative layers 166 and 167. A serpentine opening in layer 166 exposes part of a wire mesh layer 168. Slits in the patches at 170, 172 and 174 allow the patch to conform to the site of implant. Selected parts of the conductive path can be covered with insulation if desired, to leave just parallel segments exposed.

Figure 18 discloses yet another embodiment defibrillation electrode 176 in which a single conductive path 178 at the distal end of a lead 180 is formed into a spiral. The path can be a coated composite cable as previously described, with a similar nominal width in the radial direction. The pitch of the spiral, i.e. radial spacing (D) between adjacent arcs in the spiral, is preferably about 3 cm. Thus the effective electrode area encompasses the outermost arc of the spiral, as indicated by the broken line at 182. The spiral includes at least two complete turns or length-portions as shown, with each turn forming an arcuate electrode segment to provide respective radially inward and outward segments 184 and 186.

Regardless of the particular embodiment, electrodes constructed in accordance with the present invention provide a substantially larger effective or phantom area than previously practical for implantable defibrillation electrodes. One reason for this is the spacing between adjacent electrode segments, resulting in more compliant electrodes, both in the sense of matching contours in body tissue, and "dynamically" in responding to muscular contractions and other sudden or rapid tissue movement, with virtually no risk of fatigue. Another feature permitting the large size is the highly conductive electrode segments and lead distal end or other feature electrically coupling the electrode segments. This ensures an acceptably low voltage gradient across even relatively large electrodes.

As previously noted, a large but segmented electrode structure results in a substantially more uniform current distribution, as compared to conventional continuous patch electrodes. Figure 19 schematically illustrates current flow, in broken lines, between a continuous patch electrode 187 and an electrode composed of parallel, spaced apart wires or segments 189. Adjacent segments 189 are quite close to one another, e.g. spaced apart from one anther a distance of about 5 mm. Because of the low impedance between adjacent segments 189, there is virtually no potential difference between these segments and intervening tissue. Most of the current flow is along the end segments 189, and very little occurs near the intermediate segments or between segments. Consequently, the electrode formed of segments 189, much like electrode 187, exhibits a non-uniform current distribution, with very high current density at the outside edges and low current density along the medial region.

In Figure 20, the current flow between two electrodes with respective segments 191 and 193 exhibits a substantially uniform current density across each electrode. Again the current flow is shown in broken lines, and illustrates the importance of sufficient spacing between adjacent electrode segments. More particularly, the segments of electrodes 191 and 193 are spaced apart from one another a sufficient distance for intervening tissue to provide substantial electrical impedance between adjacent electrode segments. Thus, each of segments 191 and 193, including the intermediate segments, responds to the opposite one of the electrode pair, permitting current densities, over the central regions of these electrodes, substantially equal to the current densities at their edges.

Figure 21 shows the relationship between the spacing between coils or adjacent and parallel electrode segments, and impedance, for groups of two, three and four segments as shown at 195, 197 and 199, respectively. In all cases the impedance is highest when adjacent segments are closest together. In all cases, increasing the spacing from 1 cm to the preferred 3 cm reduces impedance, and the cases show some further improvement as spacing is increased beyond 3 cm. For any selected spacing, the four segment electrode exhibits the lowest impedance, which is not surprising in view of the fact that larger electrodes generally exhibit lower impedance.

Thus, it has been found that electrode performance is substantially improved, in terms of reduced impedance as well as uniformity of the electrical field, when the spacing between adjacent segments is at least 1.5 cm. The upper limit of spacing is less strict, and subject to physical (size and patient comfort) constraints rather than electrical performance constraints. Within these limits, the optimum spacing depends upon the materials employed and the intended location of implant. Gener-

ally, however, a spacing of 3 cm between adjacent electrode segments has been found satisfactory.

Figure 22 schematically illustrates an implanted defibrillation system including spaced apart electrodes 188 and 190, for example similar to electrode 16. The defibrillation system further includes a pulse generator 192, and leads 194 and 196 connecting the pulse generator to electrodes 188 and 190, respectively. Both of the electrodes are subcutaneous and outside of the rib cage, in the thoracic region. The electrodes are on opposite sides of the heart 198. More particularly, electrode 188 is positioned to the left of, and anterior with respect to, the heart. Electrode 190 is posterior with respect to the heart, and to the right of the heart. Such transthoracic application of defibrillation pulses requires electrodes having a large surface area, achieved in accordance with the present invention by the spaced apart electrode segments of each electrode. Pulse generator 192 is also mounted anterior and to the left of heart 198, below electrode 188. The pulse generator can incorporate circuitry for sensing cardiac electrical activity, in which case electrodes 188 and 190 are used in sensing such activity as well as delivering defibrillation pulses.

Figure 23 discloses a defibrillation system in which an electrode 200 constructed in accordance with the present invention is coupled to a defibrillation pulse generator 202 by a lead 204. Another electrode 206, also constructed according to the present invention, is applied directly to epicardial tissue. Electrode 200 is positioned inside of rib cage 207, and can be within the pleural cavity if desired. Stimulation occurs across the heart, with electrode 200 to the left of the heart and electrode 206 at the right ventricle.

Figure 24 shows a defibrillation electrode system including an electrode 208 positioned anterior of and to the left of the heart 210, as in Figure 22. A second electrode 212 is provided as a coil, near the distal end of an intravascular catheter 214 in the right atrium and terminating at the apex of the right ventricle.

Regardless of the location of implant, electrodes, constructed in accordance with the present invention provide relatively large (in the range of 100-300 square cm) effective areas, yet readily conform to contours and contractions or other movement of body tissue. The narrow electrode segments are provided with end loops or other enlargements to counteract high current densities due to edge effects and to provide fixation. The present lead configurations further allow a subcutaneous implantation outside of the rib cage, with effective defibrillation energy production due to large virtual sizes based on the phantom areas incorporating the electrode segments.

Claims

1. A body implantable tissue stimulating electrode assembly (16,86,122,176), including:

an elongate, electrically conductive lead (26) having a proximal end region and a distal end region (24); and

an electrode including a plurality of compliant, electrically conductive electrode segments (18,20,22) and a connecting means (24) for coupling the segments at the distal end region of the lead for substantially simultaneous reception of tissue stimulating electrical pulses from a pulse generating means at the proximal end of the lead, each of said electrode segments (18,20,22) having a nominal width and a length substantially longer than the nominal width, said electrode segments being arranged in spaced apart and side-by-side relation such that each of the electrode segments, over most of its length, is spaced apart from each one of the other electrode segments by a distance of at least 1.5 cm, said electrode segments when receiving the tissue stimulating pulses cooperating to define an effective electrode area (42) incorporating all of the electrode segments and having a width of at least 1.5 cm, and wherein said electrode segments are not formed from a wire braid.

2. The assembly of Claim 1 wherein:

said electrode segments (18,20,22) are linear, and in parallel, spaced apart relation to one another.

3. The assembly of Claim 2 wherein:

said electrode segments (18,20,22) extend in a longitudinal direction, and said connecting means (24) comprises said distal region (24) of lead (26), connected to respective first end portions of the electrode segments along said distal region.

4. The assembly of Claim 3 further including:

an electrically insulative layer (28) covering the lead distal end region.

5. The assembly of Claim 3 further including:

an elongate, electrically conductive and transversely extended coupling path (24) connected to respective second and opposite end portions of said electrode segments (18,20,22).

6. The assembly of Claim 5 further including:

an electrically insulative layer (28) covering the lead distal end region (24) and coupling path.

7. The assembly of Claim 1 wherein:

each of said electrode segments (22) includes at least one electrically conductive cable having a conductive core of silver (30) within a conductive metal tube (32), and a layer (34) covering the tube and consisting essentially of one or more of the following: platinum, iridium, ruthenium and palladium.

8. The assembly of Claim 7 wherein:

each of the electrode segments (22) includes

a plurality of said wires (76) wound together in a twisted configuration.

9. The assembly of Claim 7 wherein:
each of the electrode segments (22) includes a flexible, electrically insulative cylindrical core (82), and at least one electrically conductive wire (84) wound in a helical coil about the cylindrical core.

10. The assembly of Claim 1 wherein:
each of the electrode segments (88,90,92) extends radially outwardly of a common junction (94,118).

11. The assembly of Claim 10 wherein:
a single electrically conductive path forms first and second ones of the electrode segments (90,92), and a third one of the segments (88) is joined to the mid-point (118) of the electrically conductive path.

12. The assembly of Claim 10 wherein:
a first one of the electrode segments (136) is formed as a distal end region (126) of the lead (124), and the remaining ones of the electrode segments (138-142) are coupled to the distal end region (126) of the first segment (136).

13. The assembly of Claim 12 further including:
an electrically insulative layer (128) substantially covering the lead (124) but leaving the distal end region exposed.

14. The implantable lead of Claim 1 wherein:
said segments (136-142) comprise portions of a single conductive wire.

15. The assembly of Claim 14 wherein:
said conductive path comprises the distal region of the lead.

16. The assembly of Claim 15 further including:
an electrically insulative layer substantially covering the lead while leaving the distal end region exposed.

17. The assembly of Claim 15 wherein:
said lead distal end region is in a serpentine configuration, with said segments (136-142) parallel to and aligned with one another, side-by-side.

18. The assembly (176) of Claim 15 wherein:
said distal end region is formed in spiral configuration.

19. The assembly of Claim 1 wherein:
said segments (18-22,88-92) have respective free ends, and include means (38-40,102-106) at the respective free ends for reducing current density.

20. The assembly of Claim 19 wherein:
said means (36-40) at the respective ends includes a loop formed at each of the free ends.

21. The assembly of Claim 19 wherein:
said means (102-106) at the respective ends includes a tab forming an enlargement at each of the free ends.

22. The assembly of Claim 19 wherein:
said means (102-106) at the respective ends includes an electrically conductive body secured to each of the free ends.

23. A body implantable defibrillation system, including:
a defibrillation pulse generator (192);
a first defibrillation electrode (188) implantable at least proximate the thoracic region, said first electrode constructed in accordance with Claim 1, said conductive lead (26) providing a first coupling means (194) electrically coupling the first defibrillation electrode (188) and the defibrillation pulse generator (192);
a second defibrillation electrode (190) implantable at least proximate the thoracic region and spaced apart from the first defibrillation electrode (188); and
a second coupling means (196) electrically coupling the defibrillation pulse generator (192) and the second electrode (190).

24. The defibrillation system of Claim 23 wherein:
the second electrode (190) is positionable in the right atrium and the right ventricle of the heart, with its distal end proximate the apex of the right ventricle.

25. The defibrillation system of Claim 24 wherein:
the first defibrillation electrode (188) is adapted for fixation to epicardial tissue.

26. The defibrillation system of Claim 24 wherein:
the first defibrillation electrode (188) is positionable inside of the pleural cavity, to the left of and anterior with respect to the heart.

27. The defibrillation system of Claim 24 wherein:
the first defibrillation electrode (188) is positionable at the sternum.

28. The defibrillation system of Claim 24 wherein:
the first defibillation electrode (188) is adapted for subcutaneous positioning proximate the pleural cavity and outside of the rib cage to the left of and anterior with respect to the heart.

29. The defibrillation system of Claim 23 wherein:
said second electrode (190) is of a construction substantially identical to that of the first defibrillation electrode (188), and wherein the first and second defibrillation electrodes are adapted for subcutaneous positioning proximate the pleural cavity, outside the rib cage and on opposite sides of the heart.

30. The defibrillation system of Claim 29 wherein:
the first defibrillation electrode (188) is positionable to the left of and anterior with the respect to he heart, and the second defibrillation electrode (190) is positionable to the right of and posterior with respect to the heart.

31. The defibrillation system of Claim 23 wherein:
said defibrillation pulse generator (192) includes circuitry for sensing cardiac electrical activity, and said first defibrillation electrode (188), when not receiving the defibrillation pulses, is usable with said circuitry in sensing cardiac electrical activity.

32. A body implantable defibrillation system including:
an electrode assembly according to Claim 1;
a defibrillation pulse generating means (192) coupled to the proximal end of the lead; and wherein
said electrode (176) has a nominal width and a length at least ten times its nominal width, said electrode arranged in a curved configuration with a plurality of length-portions (184,186) of the electrode disposed in side-by-side alignment and in substantially parallel, spaced apart relation, with the separation between adjacent length-portions in a direction perpendicular to the length-portions, being at least 1.5 cm.

33. The assembly of Claim 32 wherein:
said electrode is arranged in a serpentine configuration, and the length-portions are linear and side-by-side.

34. The assembly of Claim 32 wherein:
said electrode (176) is arranged in a spiral configuration, with each of said length-portions (184-186) comprising an arcuate sector of the spiral.

35. The assembly of Claim 32 wherein:
said nominal width is at most 2.5 cm.

Patentansprüche

1. Körperimplantierbare gewebestimulierende Elektrodenanordnung (16, 86, 122, 176), welche aufweist:
eine längliche, elektrisch leitende Leitung (26) mit einem proximalen Endbereich und einem distalen Endbereich (24); und
eine Elektrode mit einer Vielzahl von nachgiebigen, elektrisch leitenden Elektrodensegmenten (18, 20, 22) und einer Verbindungseinrichtung (24) zum Koppeln der Segmente am distalen Endbereich der Leitung zum im wesentlichen gleichzeitigen Empfang von gewebestimulierenden elektrischen Impulsen von einer Impulserzeugungseinrichtung am proximalen Ende der Leitung, wobei jedes Elektrodensegment (18, 20, 22) eine Nennbreite und eine Länge hat, die wesentlich länger als die Nennbreite ist, wobei die Elektrodensegmente derart beabstandet und Seite an Seite angeordnet sind, daß jedes Elektrodensegment über den größten Teil seiner Länge von jedem anderen Elektrodensegment mit einem Abstand von wenigstens 1,5 cm beabstandet ist, wobei die Elektrodensegmente beim Empfang der gewebestimulierenden Impulse zusammenwirken, um eine effektive Elektrodenfläche (42) zu definieren, welche alle Elektrodensegmente einschließt und eine Breite von wenigstens 1,5 cm hat, und wobei die Elektrodensegmente nicht aus einem Drahtgeflecht gebildet sind.

2. Anordnung nach Anspruch 1, wobei:
die Elektrodensegmente (18, 20, 22) linear und parallel zueinander beabstandet sind.

3. Anordnung nach Anspruch 2, wobei:
die Elektrodensegmente (18, 20, 22) sich in Längsrichtung erstrecken und die Verbindungseinrichtung (24) einen distalen Bereich (24) der Leitung (26) umfaßt, der mit den entsprechenden ersten Endabschnitten der Elektrodensegmente längs des distalen Bereiches verbunden ist.

4. Anordnung nach Anspruch 3, welche ferner enthält:
eine elektrisch isolierende Schicht (28), welche den distalen Endbereich der Leitung abdeckt.

5. Anordnung nach Anspruch 3, welche ferner enthält:
einen länglichen, elektrisch leitenden und sich in Querrichtung erstreckenden Kopplungspfad (24), der mit den entsprechenden zweiten und gegenüberliegenden Endabschnitten der Elektrodensegmente (18, 20, 22) verbunden ist.

6. Anordnung nach Anspruch 5, welche ferner enthält:
eine elektrisch isolierende Schicht (28), welche den distalen Endbereich (24) der Leitung und den Kopplungspfad abdeckt.

7. Anordnung nach Anspruch 1, wobei:
jedes Elektrodensegment (22) wenigstens ein elektrisch leitendes Kabel mit einem leitenden Silberkern (30) innerhalb eines leitenden Metallrohres (32) aufweist, und eine Schicht (34), welche das Rohr bedeckt und im wesentlichen aus einem oder mehreren der folgenden besteht: Platin, Iridium, Ruthenium und Palladium.

8. Anordnung nach Anspruch 7, wobei:
jedes Elektrodensegment (22) eine Vielzahl der Drähte (76) enthält, die in einer verdrillten Ausgestaltung zusammengewickelt sind.

9. Anordnung nach Anspruch 7, wobei:
jedes Elektrodensegment (22) einen flexiblen, elektrisch isolierenden zylindrischen Kern (82) und wenigstens einen elektrisch leitenden Draht (84) aufweist, der in einer spiralförmigen Spule um den zylindrischen Kern herum gewickelt ist.

10. Anordnung nach Anspruch 1, wobei:
jedes Elektrodensegment (88, 90, 92) sich radial nach außen von einer gemeinsamen Verbindung (94, 118) erstreckt.

11. Anordnung nach Anspruch 10, wobei:
ein einziger elektrisch leitender Pfad das erste und zweite der Elektrodensegmente (90, 92) bildet, und ein drittes Segment (88) mit dem Mittelpunkt (118) des elektrisch leitenden Pfads verbunden ist.

12. Anordnung nach Anspruch 10, wobei:
ein erstes Elektrodensegment (136) als ein distaler Endbereich (126) der Leitung (124) ausgebildet ist, und die übrigen Elektrodensegmente (138-142) mit dem distalen Endbereich (126) des ersten Segments (136) verbunden sind.

13. Anordnung nach Anspruch 12, welche ferner enthält:
eine elektrisch isolierende Schicht (128), die im wesentlichen die Leitung (124) abdeckt, jedoch den distalen Endbereich frei läßt.

14. Implantierbare Leitungen nach Anspruch 1, wobei:
die Segement (136-142) Abschnitte eines einzigen leitenden Drahtes umfassen.

15. Anordnung nach Anspruch 14, wobei:
der leitende Pfad den distalen Bereich der Leitung umfaßt.

16. Anordnung nach Anspruch 15, welche ferner enthält:
eine elektrisch isolierende Schicht, die im wesentlichen die Leitung abdeckt, während sie den distalen Endbereich frei läßt.

17. Anordnung nach Anspruch 15, wobei:
der distale Endbereich der Leitung serpentinenartig ausgebildet ist, wobei diese Segemente (136-142) parallel und Seite an Seite zueinander ausgerichtet sind.

18. Anordnung (176) nach Anspruch 15, wobei:
der distale Endbereich spiralförmig ausgebildet ist.

19. Anordnung nach Anspruch 1, wobei:
die Segmente (18-22, 88-92) entsprechende freie Enden haben und eine Einrichtung (38-40, 102-106) an den entsprechenden freien Enden zum verringern der Stromdichte enthalten.

20. Anordnung nach Anspruch 19, wobei:
die Einrichtung (36-40) an den jeweiligen Enden eine Schleife enthalten, die an jedem der freien Enden ausgebildet ist.

21. Anordnung nach Anspruch 19, wobei:
die Einrichtung (102-106) an den entsprechenden Enden einen Lappen enthält, welcher eine Vergrößerung an jedem der freien Enden bildet.

22. Anordnung nach Anspruch 19, wobei:
die Einrichtung (102-106) an den entsprechenden Enden einen elektrisch leitenden Körper enthält, der an jedem der freien Enden befestigt ist.

23. Körperimplantierbares Defibrillationssystem, welches enthält:
einen Defibrillationsimpulsgenerator (192);
eine erste Defibrillationselektrode (188), die wenigstens in der Nähe des Thoraxbereiches implantierbar ist, wobei die erste Elektrode gemäß Anspruch 1 ausgebildet ist, wobei die leitende Leitung (26) eine erste Kopplungseinrichtung (194) schafft, welche die erste Defibrillationselektrode (188) und den Defibrillationsimpulsgenerator (192) elektrisch verbindet;
eine zweite Defibrillationselektrode (190), welche wenigstens in der Nähe des Thoraxbereiches implantierbar und von der Defibrillationselektrode (188) beabstandet ist; und
eine zweite Kopplungseinrichtung (196), welche den Defibrillationsimpulsgenerator (192) und die zweite Elektrode (190) elektrisch verbindet.

24. Defibrillationssystem nach Anspruch 23, wobei:
die zweite Elektrode (190) im rechten Atrium und dem rechten Ventrikel des Herzens positionierbar ist, wobei ihr distales Ende in der Nähe der Spitze des rechten Ventrikels angeordnet ist.

25. Defibrillationssystem nach Anspruch 24, wobei:
die erste Defibrillationselektrode (188) zur Befestigung am Epikardgewebe angepaßt ist.

26. Defibrillationssystem nach Anspruch 24, wobei:
die erste Defibrillationselektrode (188) innerhalb des Brustraums auf der linken Seite und vor dem Herz anordenbar ist.

27. Defibrillationssystem nach Anspruch 24, wobei:
die erste Defibrillationselektrode (188) am Brustbein anordenbar ist.

28. Defibrillationssystem nach Anspruch 24, wobei: die erste Defibrillationselektrode (188) für die subkutane Positionierung in der Nähe des Brusthohlraumes und außerhalb des Brustkorbes auf der linken Seite und vor dem Herz angepaßt ist.

29. Defibrillationssystem nach Anspruch 23, wobei: die zweite Elektrode (190) einen Aufbau hat, der im wesentlichen identisch zu demjenigen der ersten Defibrillationselektrode (188) ist, und wobei die erste und zweite Defibrillationselektrode für die subkutane Positionierung in der Nähe des Brusthohlraumes außerhalb des Brustkorbs und auf gegenüberliegenden Seiten des Herzens angepaßt ist.

30. Defibrillationssystem nach Anspruch 29, wobei: die erste Defibrillationselektrode (188) auf der linken Seite und vor dem Herz positionierbar ist, und die zweite Defibrillationselektrode (190) auf der rechten Seite und hinter dem Herz positionierbar ist.

31. Defibrillationssystem nach Anspruch 23, wobei: der Defibrillationsimpulsgenerator (192) eine Schaltung zum Abfühlen der elektrischen Herzaktivität aufweist, und die erste Defibrillationselektrode (188), wenn sie keine Defibrillationsimpulse empfängt, zusammen mit der Schaltung die elektrische Herzaktivität abfühlen kann.

32. Körperimplantierbares Defibrillationssystem, welches enthält:
eine Elektrodenanordnung nach Anspruch 1;
eine Defibrillationsimpulserzeugungseinrichtung (192), die mit dem proximalen Ende der Leitung gekoppelt ist; und wobei
die Elektrode (176) eine Nennbreite und eine Länge hat, die wenigstens das Zehnfache ihrer Nennbreite ist, wobei die Elektrode gekrümmt ausgebildet ist, wobei eine Vielzahl von Längenabschnitten (184, 186) der Elektrode in einer Seite-an-Seite-Ausrichtung und im wesentlichen parallel beabstandet angeordnet sind, wobei die Trennung zwischen benachbarten Längenabschnitten in einer Richtung senkrecht zu den Längenabschnitten wenigstens 1,5 cm ist.

33. Anordnung nach Anspruch 32, wobei: die Elektrode in einer serpentinenartigen Ausgestaltung angeordnet ist, und die Längenabschnitte linear und Seite-an-Seite angeordnet sind.

34. Anordnung nach Anspruch 32, wobei: die Elektrode (176) in einer spiralförmigen Ausgestaltung angeordnet ist, wobei jeder Längenabschnitt (184, 186) einen bogenförmigen Abschnitt der Spirale umfaßt.

35. Anordnung nach Anspruch 32, wobei: die Nennbreite höchstens 2,5 cm ist.

Revendications

1. Ensemble d'électrodes de stimulation de tissu, implantable dans le corps (16, 86, 122, 176), comprenant :
un fil allongé, électriquement conducteur (26) ayant une zone d'extrémité proximale et une zone d'extrémité distale (24) ; et
une électrode comprenant une pluralité de segments d'électrode souples et électriquement conducteurs (18, 20, 22) et un moyen de connexion (24) pour raccorder les segments au niveau de la zone d'extrémité distale du fil conducteur pour recevoir sensiblement simultanément des impulsions électriques de stimulation de tissu, provenant d'un moyen générateur d'impulsions situé au niveau de l'extrémité proximale du fil conducteur, chacun desdits segments d'électrodes (18, 20, 22) ayant une largeur nominale et une longueur sensiblement supérieure à la largeur nominale, lesdits segments d'électrode étant disposés selon une relation d'écartement et côte à côte, de telle manière que chacun des segments d'électrode soit écarté, sur la majeure partie de sa longueur, de chacun des autres segments d'électrode d'une distance d'au moins 1,5 cm, lesdits segments d'électrode coopérant, à réception des impulsions de stimulation de tissu, pour définir une surface utile d'électrode (42) englobant tous les segments d'électrode et ayant une largeur d'au moins 1,5 cm, et dans lequel lesdits segments d'électrode ne sont pas formés à partir d'une tresse de fils métalliques.

2. Ensemble selon la revendication 1, dans lequel :
lesdits segments d'électrode (18, 20, 22) sont linéaires et disposés parallèlement les uns aux autres, avec une relation d'écartement entre eux.

3. Ensemble selon la revendication 2, dans lequel :
lesdits segments d'électrode (18, 20, 22) s'étendent dans un sens longitudinal, ledit moyen de connexion (24) comprenant ladite zone distale (24) du fil conducteur (26), relié aux premières parties d'extrémité respectives des segments d'électrode le long de ladite zone distale.

4. Ensemble selon la revendication 3, comprenant en outre :
une couche électriquement isolante (28) recouvrant la zone d'extrémité distale du fil conducteur.

5. Ensemble selon la revendication 3, comprenant en outre :
un chemin de couplage (24) allongé, électriquement conducteur et prolongé transversalement,

relié aux secondes parties d'extrémité, opposées respectives desdits segments d'électrode (18, 20, 22).

6. Ensemble selon la revendication 5, comprenant en outre :
une couche électriquement isolante (28) recouvrant la zone d'extrémité distale (24) du fil conducteur et le chemin de couplage.

7. Ensemble selon la revendication 1, dans lequel :
chacun desdits segments d'électrode (22) comprend au moins un câble électriquement conducteur ayant une âme conductrice en argent (30) à l'intérieur d'un tube métallique conducteur (32), et une couche (34) recouvrant le tube et consistant essentiellement en un ou plusieurs des éléments suivants :
platine, iridium, ruthénium et palladium.

8. Ensemble selon la revendication 7, dans lequel :
chacun des segments d'électrode (22) comprend une pluralité desdits fils (76) enroulés ensemble en une configuration torsadée.

9. Ensemble selon la revendication 7, dans lequel :
chacun des segments d'électrode (22) comprend une âme cylindrique, souple et électriquement isolante (82), et au moins un fil électriquement conducteur (84) enroulé en une spirale autour de l'âme cylindrique.

10. Ensemble selon la revendication 1, dans lequel :
chacun des segments d'électrode (88, 90, 92) s'étend radialement vers l'extérieur à partir d'une jonction commune (94, 118).

11. Ensemble selon la revendication 10, dans lequel :
un seul chemin électriquement conducteur forme le premier et le deuxième (90, 92) des segments d'électrode, un troisième (88) des segments étant raccordé au point médian (118) du chemin électriquement conducteur.

12. Ensemble selon la revendication 10, dans lequel :
un premier (136) des segments d'électrode est formé en tant que zone d'extrémité distale (126) du fil conducteur (124), les autres (138 à 142) des segments d'électrode étant reliés à la zone d'extrémité distale (126) du premier segment (136).

13. Ensemble selon la revendication 12, comprenant en outre :
une couche électriquement isolante (128) recouvrant sensiblement le fil conducteur (124) mais en laissant exposée la zone d'extrémité distale.

14. Fil conducteur implantable selon la revendication 1, dans lequel :
lesdits segments (136 à 142) comprennent des parties d'un fil métallique conducteur unique.

15. Ensemble selon la revendication 14, dans lequel :
ledit chemin conducteur comprend la zone distale du fil conducteur.

16. Ensemble selon la revendication 15, comprenant en outre :
une couche électriquement isolante, recouvrant sensiblement le fil conducteur tout en laissant exposée la zone d'extrémité distale.

17. Ensemble selon la revendication 15, dans lequel :
ladite zone d'extrémité distale du fil conducteur est en forme de serpentin, lesdits segments (136 à 142) étant parallèles et alignés entre eux, côte à côte.

18. Ensemble (176) selon la revendication 15, dans lequel :
ladite zone d'extrémité distale se présente sous la forme d'une spirale.

19. Ensemble selon la revendication 1, dans lequel :
lesdits segments (18 à 22, 88 à 92) ont des extrémités libres respectives et comprennent des moyens (38 à 40, 102 à 106) au niveau des extrémités libres respectives pour réduire la densité de courant.

20. Ensemble selon la revendication 19, dans lequel :
lesdits moyens (36 à 40), au niveau des extrémités respectives, comprennent une boucle formée au niveau de chacune des extrémités libres.

21. Ensemble selon la revendication 19, dans lequel :
lesdits moyens (102 à 106), au niveau des extrémités respectives, comprennent une oreille constituant un élargissement au niveau de chacune des extrémités libres.

22. Ensemble selon la revendication 19, dans lequel :
lesdits moyens (102 à 106), au niveau des extrémités libres comprennent un corps électriquement conducteur, fixé à chacune des extrémités libres.

23. Système de défibrillation, implantable dans le corps, comprenant :
un générateur d'impulsions de défibrillation (192) ;
une première électrode de défibrillation (188), implantable au moins à proximité de la zone thoracique, ladite première électrode étant réalisée selon la revendication 1, ledit fil conducteur (26) constituant un premier moyen de couplage (194) reliant électriquement la première électrode de défibrillation (188) et le générateur d'impulsions de défi-

brillation (192) ;

une deuxième électrode de défibrillation (190), implantable au moins à proximité de la zone thoracique et écartée de la première électrode de défibrillation (188) ; et

un deuxième moyen de couplage (196) reliant électriquement le générateur d'impulsions de défibrillation (192) et la deuxième électrode (190).

24. Système de défibrillation selon la revendication 23, dans lequel :

la deuxième électrode (190) peut être placée dans l'oreillette droite et le ventricule droit du coeur, son extrémité distale étant proche de l'apex du ventricule droit.

25. Système de défibrillation selon la revendication 24, dans lequel :

la première électrode de défibrillation (188) est propre à être fixée au tissu épicardial.

26. Système de défibrillation selon la revendication 24, dans lequel :

la première électrode de défibrillation (188) peut être placée à l'intérieur de la cavité pleurale, sur la gauche et à l'avant par rapport au coeur.

27. Système de défibrillation selon la revendication 24, dans lequel :

la première électrode de défibrillation (188) peut être placée au niveau du sternum.

28. Système de défibrillation selon la revendication 24, dans lequel :

la première électrode de défibrillation (188) convient à une mise en place sous-cutanée, à proximité de la cavité pleurale et à l'extérieur de la cage thoracique, sur la gauche et à l'avant par rapport au coeur.

29. Système de défibrillation selon la revendication 23, dans lequel :

ladite deuxième électrode (190) est de structure sensiblement identique à celle de la première électrode de défibrillation (188), et dans lequel la première et la deuxième électrodes de défibrillation conviennent à une mise en place sous-cutanée, à proximité de la cavité pleurale, à l'extérieur de la cage thoracique et sur les côtés opposés du coeur.

30. Système de défibrillation selon la revendication 29, dans lequel :

la première électrode de défibrillation (188) peut être placée sur la gauche et à l'avant par rapport au coeur, la deuxième électrode de défibrillation (190) pouvant être placée sur la droite et à l'arrière par rapport au coeur.

31. Système de défibrillation selon la revendication 23, dans lequel :

ledit générateur d'impulsions de défibrillation (192) comprend des circuits pour détecter l'activité électrique cardiaque ladite première électrode de défibrillation (188) pouvant être utilisée lorsqu'elle ne reçoit pas les impulsions de défibrillation, avec lesdits circuits pour détecter l'activité électrique cardiaque.

32. Système de défibrillation implantable dans le corps comprenant :

un ensemble d'électrodes selon la revendication 1 ;

un moyen générateur d'impulsions de défibrillation (192), relié à l'extrémité proximale du fil conducteur ; et dans lequel

ladite électrode (176) a une largeur nominale et une longueur d'au moins dix fois sa largeur nominale, ladite électrode étant prévue selon une forme courbe, une pluralité de parties de longueur (184, 186) de l'électrode étant disposée en un alignement côte à côte et avec une relation écartée et sensiblement parallèle, la séparation entre des parties adjacentes de longueur, dans un sens perpendiculaire aux parties de longueur, étant d'au moins 1,5 cm.

33. Ensemble selon la revendication 32, dans lequel :

ladite électrode est disposée en une forme de serpentin, les parties de longueur étant linéaires et côte à côte.

34. Ensemble selon la revendication 32, dans lequel :

ladite électrode (176) est disposée en spirale, chacune desdites parties de longueur (184 à 186) comprenant un secteur arqué de la spirale.

35. Ensemble selon la revendication 32, dans lequel :

Ladite largeur nominale est de 2,5 cm au maximum.

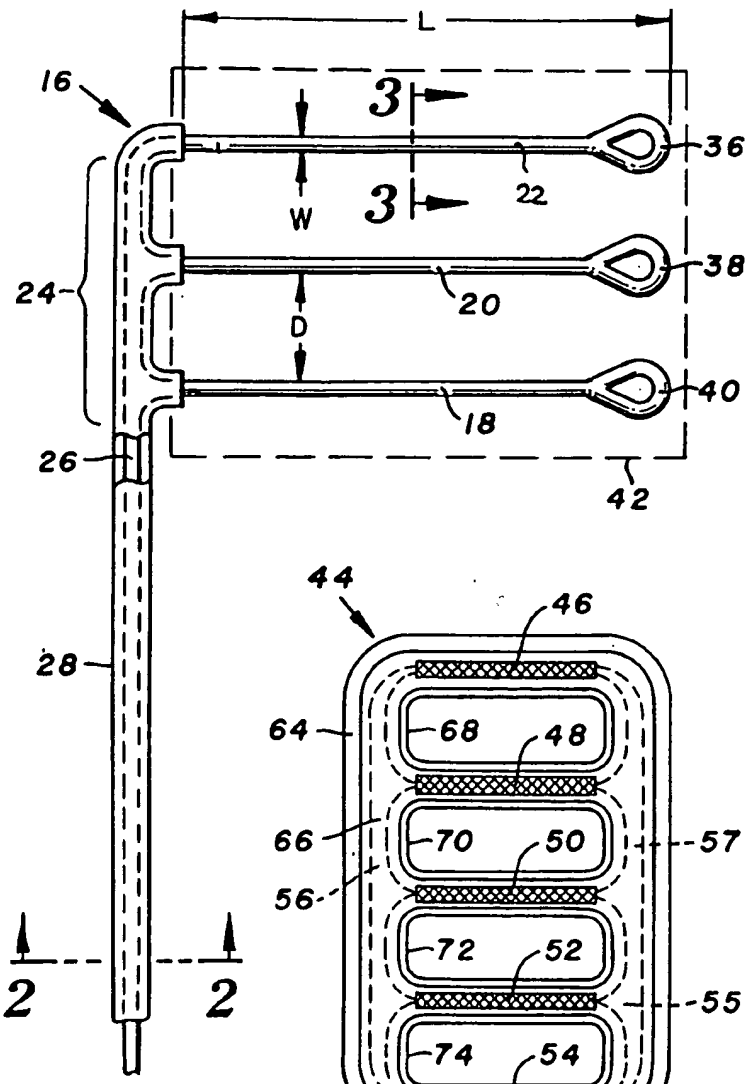

FIG. 1

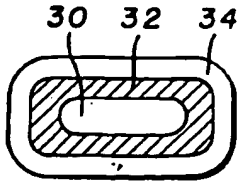

FIG. 2

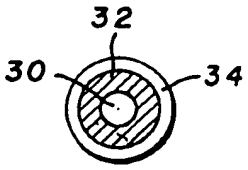

FIG. 3

FIG. 4

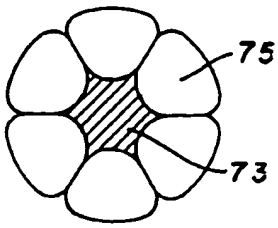

FIG. 5

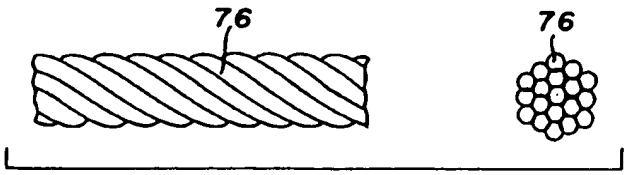

FIG.6

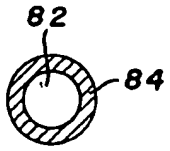

FIG.8

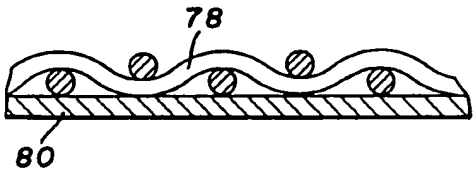

FIG.7

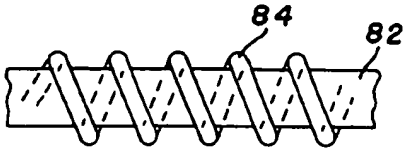

FIG.9

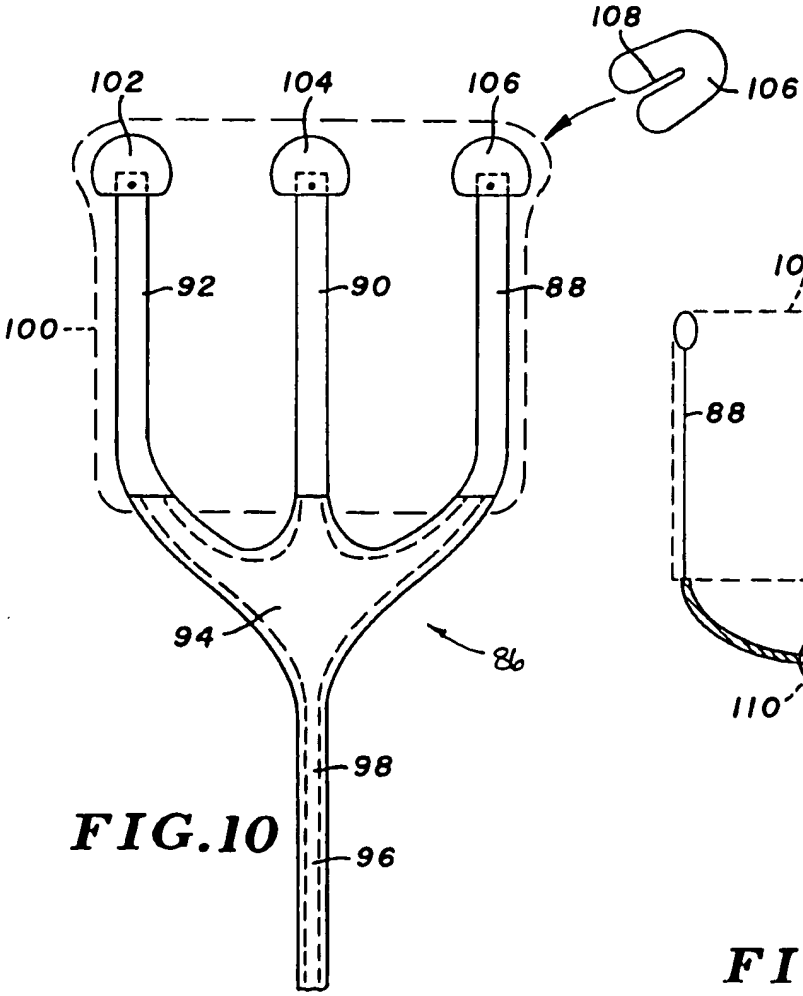

FIG.10

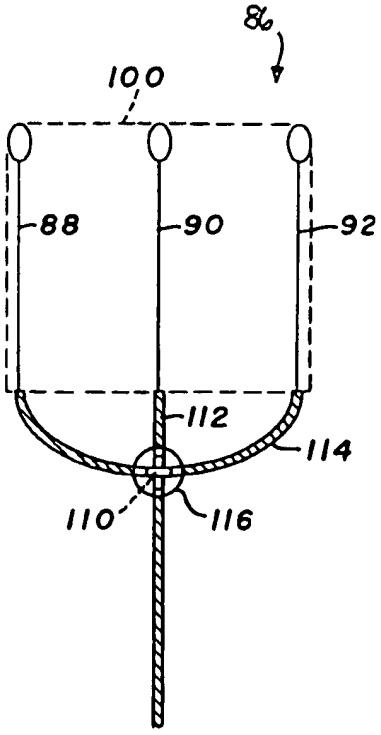

FIG.11

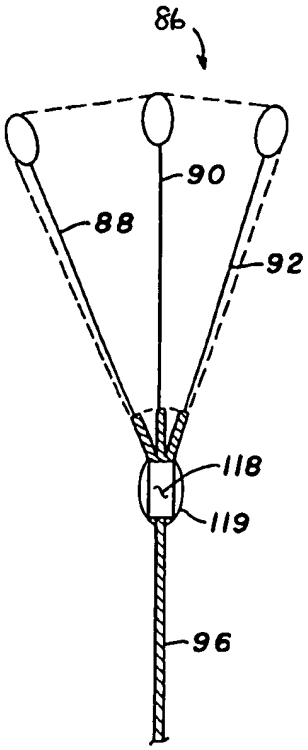

FIG.12

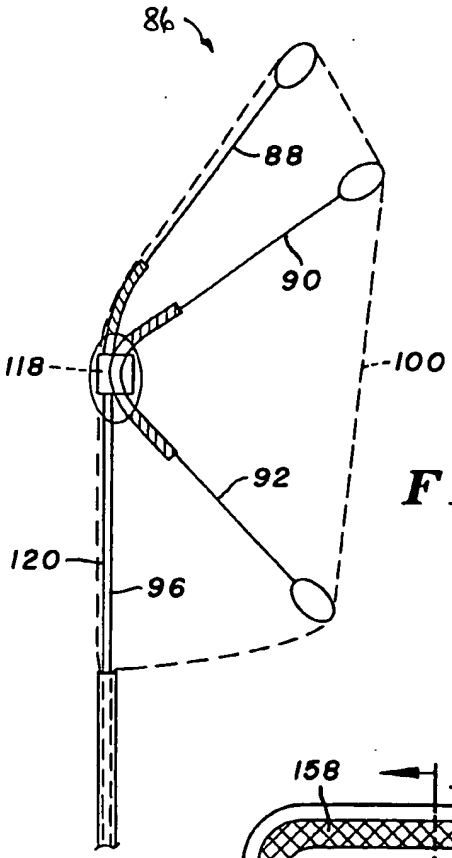

FIG.13

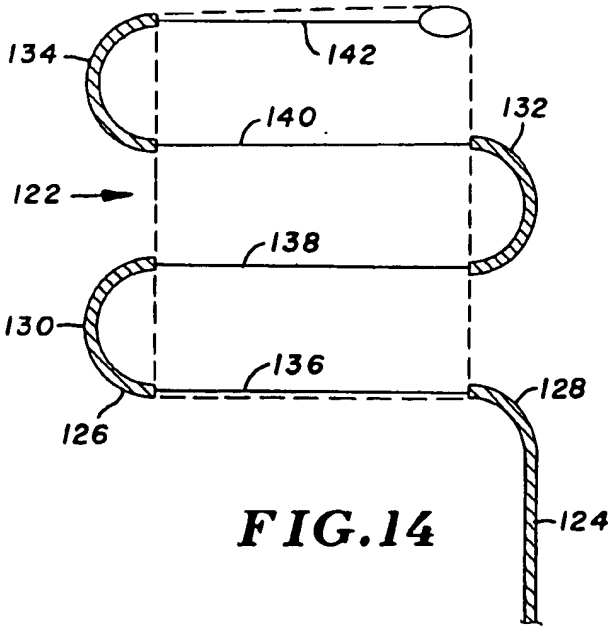

FIG.14

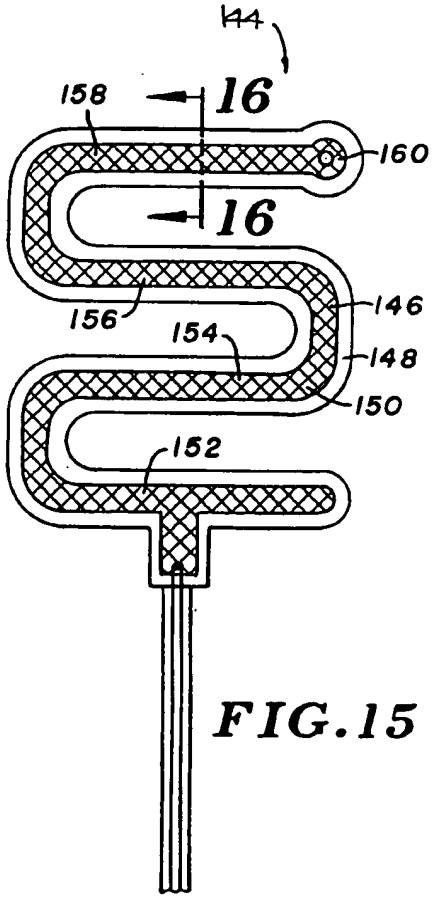

FIG.15

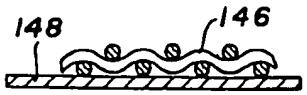

FIG.16

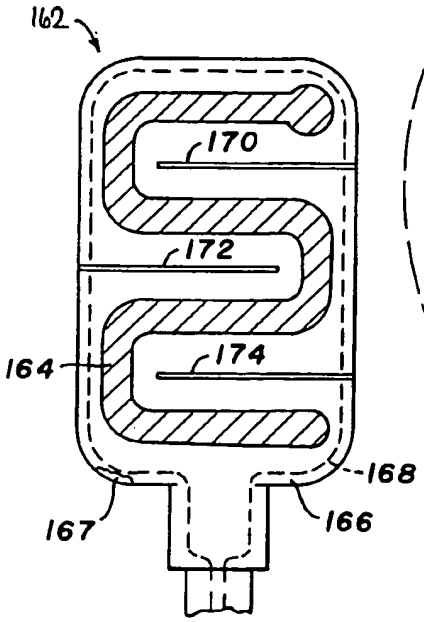

FIG.17

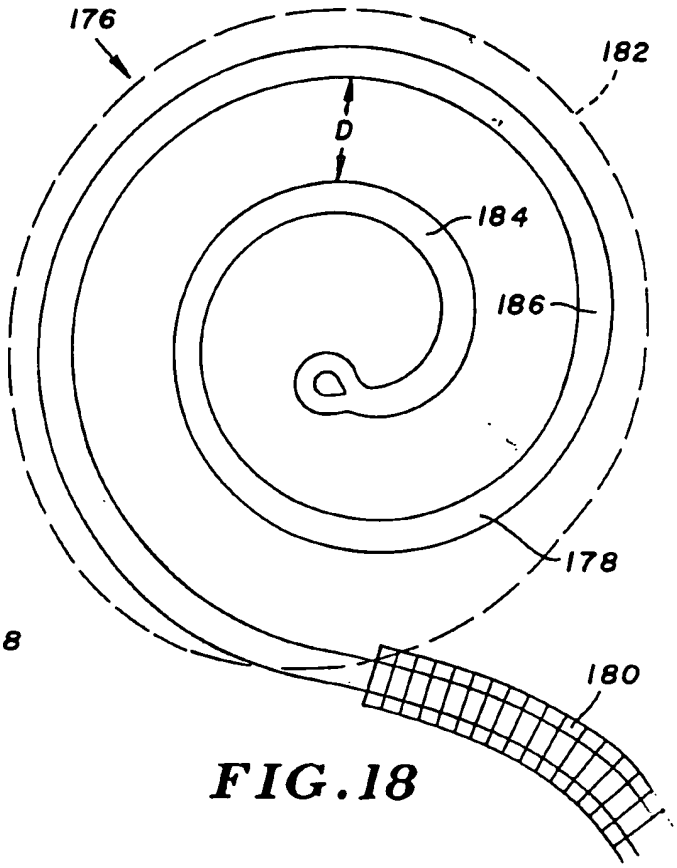

FIG.18

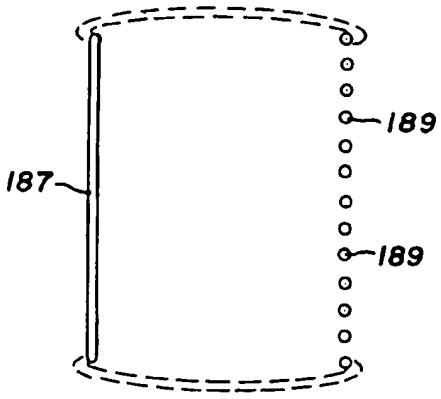

FIG.19

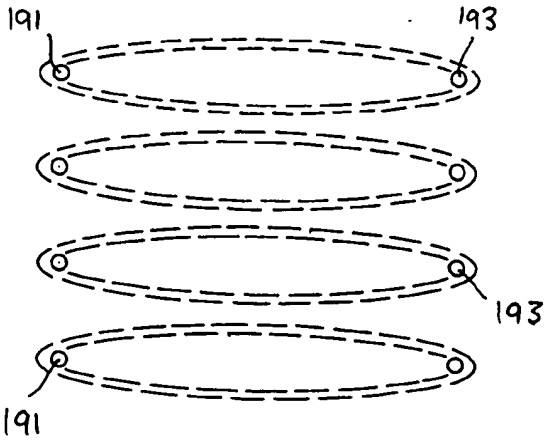

FIG.20

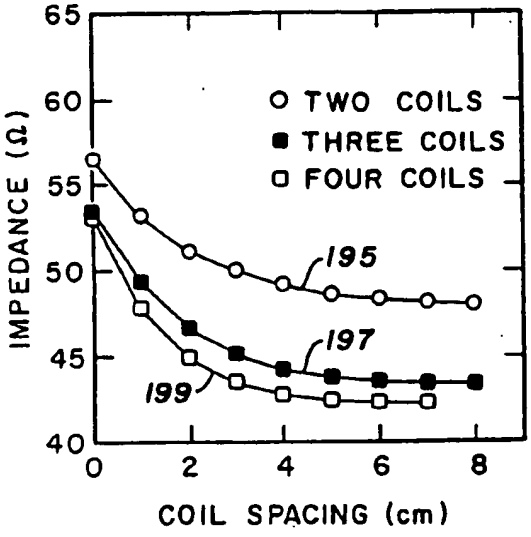

FIG. 21

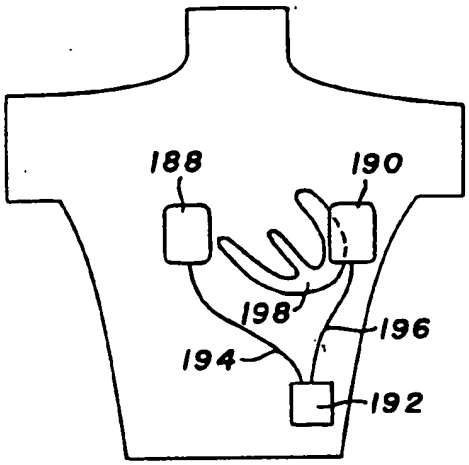

FIG. 22

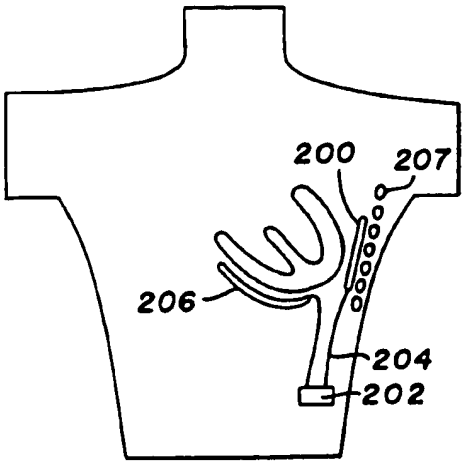

FIG. 23

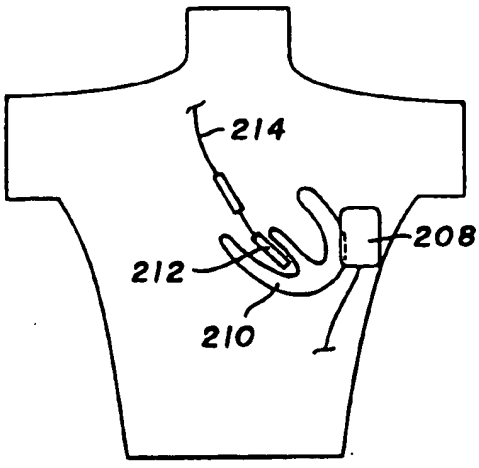

FIG. 24